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A Review of Standards of Performance for New Stationary Sources Secondary Brass and Bronze Plants

MITRE Corp, McLean, VA METREK Div

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This report reviews the current Standards of Performance for New Stationary Sources: Subpart M - Secondary Brass and Bronze Ingot Production Plants. Emphasis is given to the state of control technology, extent to which plants would be able to meet current standards and future trends in the brass and bronze industry. Information used in this report is based upon data available as of October 1978. A general recommendation is made to retain the current standard. Other recommendations include periodic studies of control technology for both metallic fume and fugitive emissions.

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1.0 EXECUTIVE SUMMARY

The objective of this report is to review the New Source Performance Standard (NSPS) for brass and bronze ingot production plants and to assess the need for revision on the basis of developments that have occurred since the original standard was promulgated on March 8, 1974. A set of conclusions is presented and specific recommendations are made with respect to EPA action in implementing changes in the NSPS.

1.1 Industry Outlook

In 1969, there were approximately 60 brass and bronze ingot production facilities in the U.S. Currently, only 35 facilities are operational, and only one facility has become operational since the promulgation of the NSPS in 1974. No new facilities or modifications are known to be currently planned or under construction.

Ingot production has shown a steady decline from the 1966 peak year production of 315,000 metric tons (Mg) (347,000 tons) to a low of 160,000 Mg (186,000 tons) in 1975, the last year for which nationwide statistics were published. The decline has been caused by a de facto decline in the demand for products made with brass or bronze and large scale substitution of other materials or technologies for the previously used brass or bronze. The likelihood of a reversal of this decline was investigated and discussed with key organizations associated with the industry. The opinion was unanimous that the decline in brass and bronze ingot production and in the number of plants operating will continue.

1.2 Best Demonstrated Control Technology

The current best demonstrated control technology, the fabric filter, is the same as that when the standards were originally promulgated. No major improvements in this technology have occurred during the intervening period.

High-pressure drop venturi scrubbers are used, to some extent, in the brass and bronze industry, but their overall control efficiency is significantly lower than that of fabric filters. Typical efficiencies are far below what would be required for adequate control under the current NSPS. Electrostatic precipitators have not been used in the industry due to both the low gas flow rates and high resistivity of metallic fumes.

Future trends in control of fine particulates, particularly metallic fumes, will most likely continue to indicate that the fabric filter is the best choice for controls. Extensive studies on both conventional and new devices indicate two important points: first, fabric filters have the highest overall efficiencies of any of the devices; and second, there is a minimum in collection efficiency in the sizes around 0.5 μm for most control devices. However, for fabric filters, the differences between this minimum and the overall efficiency are almost negligible. This is a very important consideration in control of metallic fumes, since most of the particles are in this size range.

1.3 Compliance Test Data

Only one facility has become subject to the NSPS since its original promulgation. This facility was tested in February 1978. The average test result of 16.9 milligrams/dry standard cubic meters (mg/dscm), or 0.0074 grains/dry standard cubic feet (gr/dscf), is lower than most of the test data used for justification of the current standard of 50 mg/dscm (0.022 gr/dscf), but this single test is not sufficient to draw any overall conclusion about improved control technology.

1.4 Possible Revision of Standard

1.4.1 Current Standard for Particulates and Opacity

No justification exists for revision of any part of the current standards for either particulates or opacity. This conclusion is based on the following considerations:

1. Fabric filter control technology has remained relatively constant since the standard was promulgated.
2. No new high temperature fabrics have become available.
3. Economic trends in the industry indicate that revision of the standard would have almost no impact on emissions throughout the nation.

1.4.2 Extension of Standard to Other Emissions

The only logical extensions of the standard to other emissions would be for control of fugitive emissions and/or control of specific particulates, such as zinc oxide. There are no specific control methods, either physical or chemical, for control of zinc oxide particles, although cooling of the gas stream can be employed to control

considerable metallic fume. However, the overall efficiency of fabric filters appears to control zinc oxide fumes to levels that do not warrant consideration of specific controls.

Fugitive emissions continue to be a problem in the brass and bronze industry. In most cases, these emissions are very difficult to capture and equally difficult to measure during testing. It was primarily for the former reason that the current particulate standard does not apply during pouring of the ingots. This overall situation has not changed in that only complete enclosure of the furnace can result in full control of fugitive emissions. However, EPA has information indicating that there may be additives capable of reducing fugitive emissions during pouring (EPA, 1979). Also improved control of fugitive emissions may be possible through improved hood design. Nevertheless, the negative growth of the industry does not appear to warrant development of a fugitive emission NSPS at this time.

1.4.3 Extension of Standard to Other Process Steps

Two process steps during scrap preparation emit appreciable amounts of particulates: burning and sweating furnace operations. Although control of such emissions is possible, industry trends indicate that the impact of such control on emissions would be negligible. Extension of the standard to any of these process steps is unjustified at present.

1.5 Final Recommendations

Based on the technological and economic findings presented in this report, the following recommendations are made:

- No extension or revision of either the particulate or opacity standards should be considered at the present time.

- Periodic studies should be made to monitor both metallic fume control technology and the economics of the brass and bronze industry.

- Review of advances in control of fugitive emissions, particularly from other metal industries, should be made periodically to determine if any workable economic techniques have been developed.

2.0 INTRODUCTION

In Section 111 of the Clean Air Act, "Standards of Performance for New Stationary Sources," a provision is set forth which requires that "The Administrator shall, at least every four years, review and, if appropriate, revise such standards following the procedure required by this subsection for promulgation of such standards." Pursuant to this requirement, the MITRE Corporation, under EPA Contract No. 68-02-2526, is to review 10 of the promulgated New Source Performance Standards (NSPS) including secondary brass and bronze ingot production plants.

The main purpose of this report is to review the current secondary brass and bronze standards for particulates and opacity and to assess the need for revision on the basis of developments that have occurred or are expected to occur in the near future. This report addresses the following issues:

1. A review of the definition of the present standards.
2. A discussion of the status of the secondary brass and bronze industry and the status of applicable control technology.
3. Analysis of compliance test results and review of level of performance of best demonstrated control technology for emission control.
4. Review of the impact of NSPS revision on secondary brass and bronze production economics, and the effect of the economic decline in the industry on any consideration to revise or extend the NSPS.

Based on the information contained in this report, a set of conclusions is presented and specific recommendations are made with respect to EPA action in implementing changes in the NSPS.

3.0 CURRENT STANDARDS FOR SECONDARY BRASS AND BRONZE SMELTERS

As a result of the 1970 Clean Air Act, New Source Performance Standards were passed that specified allowable levels of emissions from several industrial sources, including secondary brass and bronze smelters (40 CFR 60). Any secondary brass or bronze smelter under construction on or after June 11, 1973 became subject to NSPS. The NSPS for secondary brass and bronze smelters were promulgated on March 8, 1974 and were later amended October 6, 1975.

3.1 Affected Facilities

The facilities of a secondary brass and bronze smelter that are subject to NSPS are reverberatory and electric furnaces of 1,000 kg (2,205 lb) or greater production capacity, and blast (cupola) furnaces of 250 kg/hr (550 lb/hr) or greater production capacity. Also affected by NSPS are modified secondary brass and bronze furnaces (a furnace that has undergone a physical or operational change that increases the emission rate of any pollutant) and reconstructed secondary brass and bronze furnaces in which the replacement cost of components exceeds 50 percent of the cost of building a comparable new facility. Since almost all brass and bronze ingot production in the U.S. is of the secondary type, the regulation essentially governs the entire industry.

3.2 Controlled Pollutants and Emission Levels

Particulate matter is the pollutant to be controlled by secondary brass and bronze smelters under the NSPS. In addition to a

particulate standard, an opacity standard is also set under the current regulations.

As stated in 40 CFR 60.132, no owner or operator of a secondary brass and bronze smelter under construction on or after June 11, 1973, "shall discharge or cause the discharge into the atmosphere from a reverberatory furnace any gases which:

1. Contain particulate matter in excess of 50 mg/dscm (0.022 gr/dscf).

2. Exhibit 20 percent opacity or greater."

In addition, any blast (cupola) or electric furnace may not emit any gases which exhibit 10 percent opacity or greater.

3.3 Testing and Monitoring Requirements

A performance test of a secondary brass and bronze smelter must be conducted within 60 days after the facility has achieved its maximum production rate and not later than 180 days after its initial startup. Such a test consists of three separate runs of which the arithmetic mean is the result for determining compliance with NSPS. If one of the runs is lost due to forced shutdown, failure of an irreplaceable portion of the sample train, extreme meteorological conditions, or other circumstances beyond the operator's control, the arithmetic mean of the remaining two runs will suffice as the performance test result, upon approval by the administrator (40 CFR 60).

Test methods to be used to determine compliance with NSPS are:

1. Method 5 for the concentration of particulate matter and the associated moisture content

2. Method 1 for sample and velocity traverses

3. Method 2 for velocity and volumetric flow rate

4. Method 3 for gas analysis.

No monitoring requirement is set for secondary brass and bronze smelters.

Alternative testing equipment or procedures may be used (upon approval by EPA) when the equipment capable of producing accurate results is not available (e.g., stack geometry and limited work space require modification of location of the pollutant sampling train), when unusual circumstances justify less costly procedures, or when the plant operator prefers to use other equipment or procedures that are consistent with current practices.

3.4 Definitions Applicable to Secondary Brass and Bronze Smelters

Terms applicable to secondary brass and bronze smelters as defined in 40 CFR 60 include:

- Blast furnace - any furnace used to recover metal from slag, which includes both the standard blast furnace and the cupola.
- Electric furnace - any furnace that uses electricity to produce over 50 percent of the heat required in the production of refined brass or bronze ingots.
- Reverberatory furnace - any furnace in which the flame or hot gases from the burning fuel come in direct contact with the charge. It includes those furnaces that are stationary, rotating, rocking or tilting.
- Testing is to be conducted during representative periods of furnace operation, including charging and tapping. However, testing during pouring of ingots is specifically excluded.

3.5 Regulatory Basis for Any Waivers, Exemptions, or Other Tolerances

Standards do not apply during periods of startup, shutdown, and malfunction. In addition, when systems of emission reduction which meet the particulate mass standard cannot meet the opacity limits, the source may be exempted from the opacity standard and a higher ad hoc opacity standard will be established for the facility (39 FR 9309, March 8, 1974).

4.0 STATUS OF CONTROL TECHNOLOGY

4.1 Recent and Forecasted Economic Trends in the Industry

The secondary copper industry is divided into two categories: (1) producers of brass and bronze ingot, billet or noncast ingot, all having a raw material input of brass and bronze scrap; and (2) producers of unalloyed copper, having a raw material input of copper scrap (Arthur D. Little, 1976). The second category is not subject to NSPS under regulations for secondary brass and bronze smelters and will not be discussed in this report. Secondary brass and bronze ingot production encompasses approximately two-thirds of all secondary copper recovery.

4.1.1 Industry Overview

Secondary brass and bronze smelters that produce brass and bronze ingots, billets, or noncast ingots are mostly small, individually owned firms that usually consist of only one plant. A few are subsidiary operations of large mining companies or of conglomerates (Arthur D. Little, 1976).

In 1969, there were approximately 60 U.S. brass and bronze ingot production facilities (U.S. Department of Health, Education and Welfare, 1969). Over the next 7 years this figure dropped to 37 facilities (Arthur D. Little, 1976). In September 1978, the U.S. Bureau of Mines listed 35 operational facilities as shown in Table 4-1 (Schroeder, 1978). Only one of these plants is new and subject to NSPS (Sherman, 1978).

TABLE 4-1

PRODUCERS OF BRASS AND BRONZE INGOTS, SEPTEMBER 1978

1. American Brass Inc., P.O. Box 185, Headland, Ala. 36345 (new plant)
2. ASARCO Incorporated, San Francisco, Calif.
3. ASARCO Incorporated, Whiting, Ind.
4. ASARCO Incorporated, Newark, N.J.
5. ASARCO Incorporated, Houston, Tex.
6. The G.A. Avril Co., Brass & Bronze Ingot Div., Box 66 Winton Place Station, 4445 Kings Run Drive, Cincinnati, Ohio 45232
7. Bay State Refining Co., Inc., P.O. Box 269, Chicopee, Mass. 01021
8. Belmont Sm. & Rfg. Wks., Inc., 330 Belmont Avenue, Brooklyn, N.Y. 11207
9. Brush Wellman Inc., 17876 St. Clair Avenue, Cleveland, Ohio 44110 - Elmore, Ohio Plant
10. W.J. Bullock, Inc., Box 539, Fairfield, Ala. 35064
11. Harry Butter & Co., Inc., 151 Mt. Vernon Street, Dorchester, Mass. 02125
12. Colonial Metals Co., P.O. Box 311, Second & Linden Sts., Columbia, Pa. 17512
13. Federal Metal Co., 7250 Division Street, Bedford, Ohio 44146
14. Benjamin Harris & Co., 11th & State Sts., Chicago Heights, Ill. 60411
15. Interstate Sm. & Rfg. Co., 9651 S. Torrence Avenue, Chicago, Ill. 60617

TABLE 4-1 (Continued)

16. N. Kamenske & Co., Inc., Box 724, 5 Otterson Court, Nashua, N.H. 03061

17. Kawecki Berylco Inds., Inc., Alloy Div., P.O. Box 1462, Reading, Pa. 19603

18. Kearny Sm. & Rfg. Corp., 936 Harrison Ave., Kearny, N.J. 07029

19. H. Kramer & Co., P.O. Box 7, No. 1 Chapman Way, El Segundo, Calif. 90246

20. H. Kramer & Co., 1339-1345 W. 21st Street, Chicago, Ill. 60608

21. R. Lavin & Sons, Inc., 3426 S. Kedzie Avenue, Chicago, Ill. 60623

22. Metallurgical Products Co., 810 Lincoln Ave., P.O. Box 598, West Chester, Pa. 19380

23. Mishawaka Brass Manufacturing Inc., 1928 Mick Court, Mishawaka, Ind. 46544

24. National Metals, Inc., Box 102, Leeds, Ala. 35094

25. New England Sm. Works, Inc., 502 Union Street, W. Springfield, Mass. 01089

26. North American Smelting Co., Marine Terminal, Wilmington, Del. 19899

27. North Chicago Rfg. & Sm. Inc., 2028 S. Sheridan Rd., N. Chicago, Ill. 60064

28. Phelps Dodge Inds., Inc., Lee Bros., P.O. Box 1229, Anniston, Ala. 36201

29. River Sm. & Rfg. Co., P.O. Box 5755, Cleveland, Ohio 44101

30. Roessing Bronze Co., P.O. Box 60, Mars, Pa. 16046

TABLE 4-1 (Concluded)

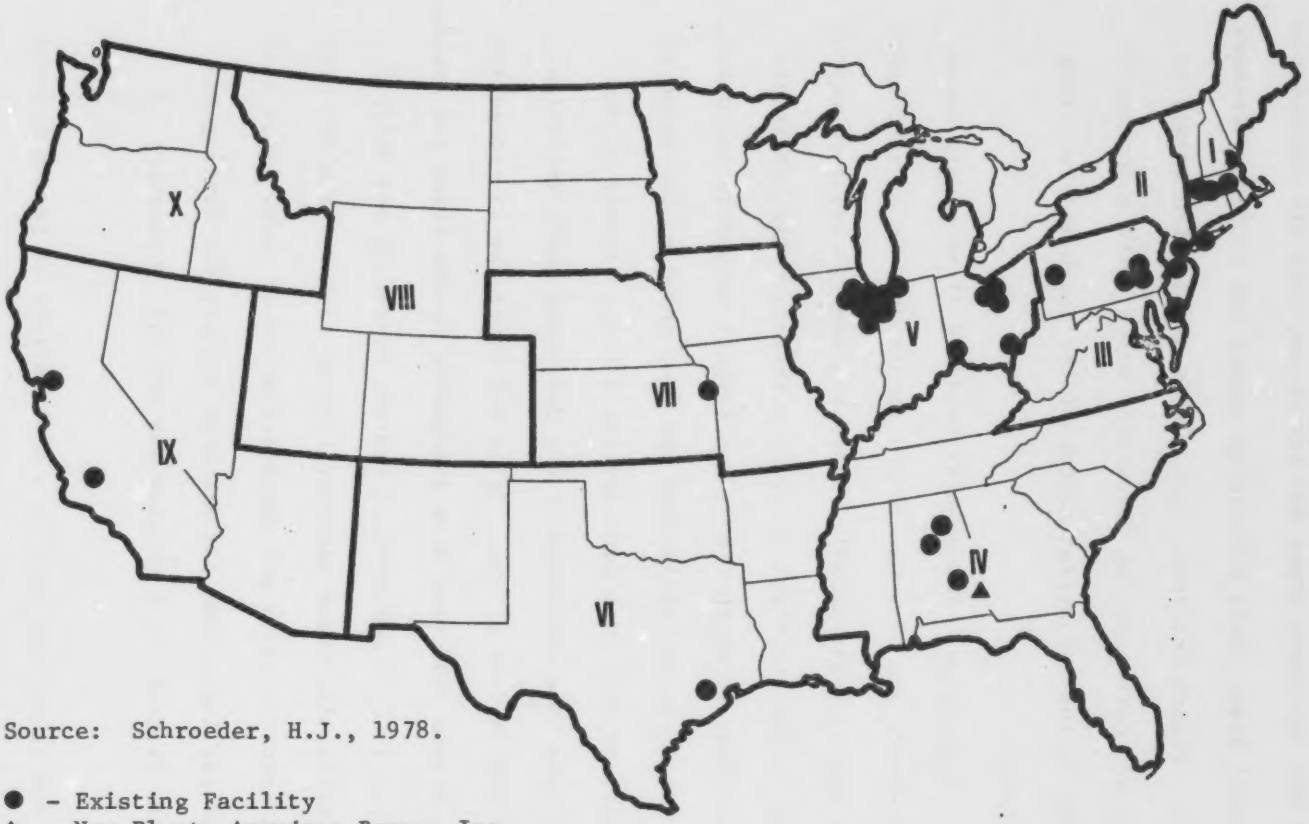
31.	S-G Metals Inds., Inc., 2nd & Riverview, Kansas City, Kan. 66110
32.	I. Schumann & Company, 22500 Alexander Road, Bedford, Ohio 44146
33.	Sipi Metals Corp., 1720 N. Elston Avenue, Chicago, Ill. 60622
34.	South Bend Sm. & Rfg. Co., 1610 Circle Avenue, South Bend, Ind. 46621
35.	Specialloy Inc., 4025 S. Keeler Avenue, Chicago, Ill. 60632

Source: Schroeder, H.J., 1978.

Most of the secondary brass and bronze smelters are located near heavy industrial areas where both scrap supply and product customers are available. Figure 4-1 shows that plants are located mainly in the northeast and north central industrial belts, with a concentration of plants in the industrial center of the South and two along the Pacific Coast.

4.1.1.1 Production. The general products of secondary brass and bronze smelters are 13.6 kg (30 lb) ingots and copper or copper-nickel alloy shot. Traditionally, brass has been an alloy of copper in which zinc is the principal alloying material, while bronze has been a copper alloy in which tin is the largest secondary component. Today these two terms are still used but they cover a wide range of alloy compositions that have been developed for a variety of end uses. These uses take advantage of the different characteristics possessed by the various alloys. Table 4-2 lists the 12 categories of brass and bronze that have been designated by the Brass and Bronze Ingot Institute (U.S. Department of Health, Education and Welfare, 1969). The table also shows subcategories of the alloys along with the chemical specifications and characteristics of each. This list parallels similar lists from the American Society for Testing and Materials, the Federal Stock Catalog and the U.S. Department of Defense.

Brass and bronze are used in a wide variety of products found in the marketplace. Table 4-3 lists the principal categories of end



Source: Schroeder, H.J., 1978.

● - Existing Facility
▲ - New Plant, American Brass, Inc.

FIGURE 4-1
LOCATION OF SECONDARY BRASS AND BRONZE INGOT PRODUCTION PLANTS

TABLE 4-2

BRASS AND BRONZE ALLOYS, CHEMICAL SPECIFICATIONS AND PRODUCT CHARACTERISTICS

Alloy No.	Classification	Cu, %	Sn, %	Pb, %	Zn, %	Fe, %	Al, %	Ni, %	Si, %	Mn, %	Characteristics
1A	Tin bronze	88.0	10.0		2.0						Corrosion resistant; good for casting.
1B	Tin bronze	88.0	8.0		4.0						
2A	Leaded tin bronze	88.0	6.0	1.5	4.0						
2B	Leaded tin bronze	87.0	8.0	1.0	4.0						
2C	Leaded tin bronze	87.0	10.0	1.0	2.0						
3A	High-lead tin bronze	80.0	10.0	10.0							Malleable; readily machined.
3B	High-lead tin bronze	83.0	7.0	7.0	3.0						
3C	High-lead tin bronze	85.0	5.0	9.0	1.0						
3D	High-lead tin bronze	78.0	7.0	15.0							
3E	High-lead tin bronze	71.0	5.0	24.0							
4A	Leaded red brass	85.0	5.0	5.0	5.0						Inexpensive, corrosion-resistant, good for casting and machining (useful for water systems).
4B	Leaded red brass	83.0	4.0	6.0	7.0						
5A	Leaded semi-red brass	81.0	3.0	7.0	9.0						
5B	Leaded semi-red brass	76.0	2.5	6.5	15.0						
6A	Leaded yellow brass	72.0	1.0	3.0	24.0						Moderately strong; easily machined and polished.
6B	Leaded yellow brass	67.0	1.0	3.0	29.0						
6C	Leaded yellow brass	61.0	1.0	1.0	37.0						
7A	Manganese bronze	59.0	1.0	1.0	37.0	1.0	0.6			0.5	High tensile strength; corrosion-resistant to sea water.
8A	Hi-strength mang. bronze	57.5			39.0	1.0	1.0			1.5	
8B	Hi-strength mang. bronze	64.0			24.0	3.0	5.0			3.5	
8C	Hi-strength mang. bronze	64.0			24.0	3.0	5.0			3.5	
9A	Aluminum bronze	88.0				3.0	9.0				High tensile strength and hardness; resistant to fatigue and high temperature
9B	Aluminum bronze	89.0				1.0	10.0				
9C	Aluminum bronze	85.0				4.0	11.0	2.0		0.5	
9D	Aluminum bronze	81.0				4.0	11.0	4.0		3.0	
10A	Leaded nickel brass	57.0	2.0	9.0	20.0			12.0			Excellent mechanical properties; tarnish and corrosion-resistant.
10B	Leaded nickel brass	60.0	3.0	5.0	16.0			16.0			
11A	Leaded nickel bronze	64.0	4.0	4.0	8.0			20.0			
11B	Leaded nickel bronze	66.5	5.0	1.5	2.0			25.0			
12A	Silicon bronze	88.0			5.0	1.5			4.0	1.5	Good for casting (leaves a clean casting surface).
12B	Silicon brass	82.0			14.0				4.0		

Source: U.S. Department of Health, Education, and Welfare, 1969.

uses. In the construction sector, plumbing fittings, domestic service tubing and water heaters account for the major part of the consumption (Monzon, 1978). In the transportation sector, large amounts of brass and bronze are used in auto manufacture, shipbuilding, and railroad rolling stock. Consumer goods include washing machines, refrigerators, radios and televisions which are considered to be important durable goods in terms of the total U.S. economy.

TABLE 4-3

END USES OF BRASS AND BRONZE

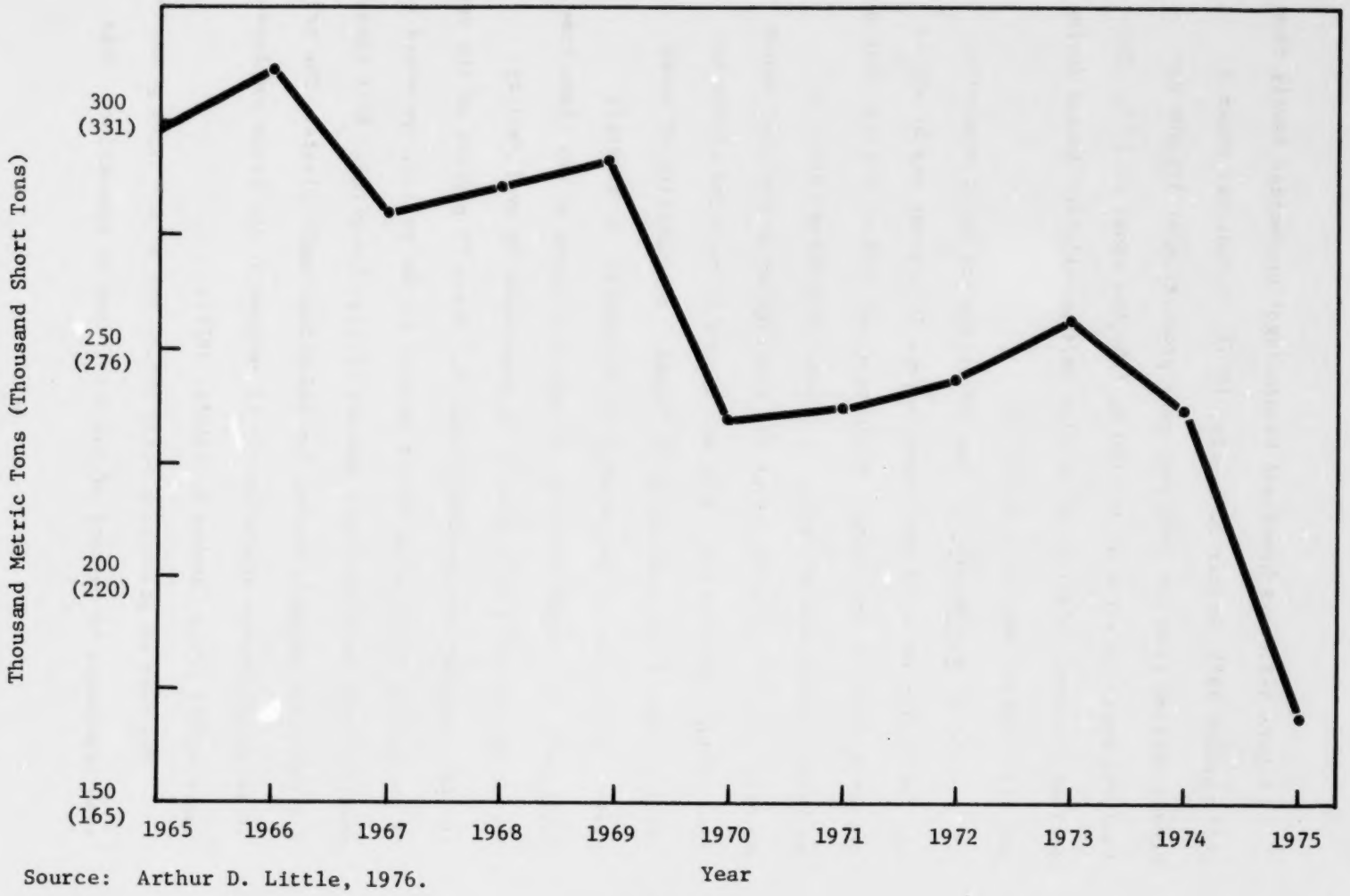
- Building Construction
  - Plumbing
  - Electrical
  - Decorative
- Transportation
- Shipbuilding
- Electrical Industry
- Communications
- Consumer Goods
- Military
  - Munitions
  - Ordinance Manufacture
  - Aircraft Manufacture
  - Naval Vessel Construction
  - Signal Equipment

Sources: Monzon, P.G., 1978; Arthur D. Little, 1976.

Figure 4-2 shows brass and bronze ingot production levels from 1965 through 1975 (Arthur D. Little, 1976). Output has shown a steady decline from the 1966 peak year production of 315,000 Mg (347,000 tons) to a low of 160,000 Mg (186,000 tons) in 1975. This decline occurred in spite of the high wartime military demand during the late sixties and early seventies.

4.1.1.2 Raw Materials. Raw materials for ingot production consist mostly of brass and bronze scrap. This scrap may be either obsolete scrap or new scrap. Obsolete scrap refers to items that are no longer useful and are being recycled. New scrap refers to materials such as pieces, chips and shavings of alloys that result from product fabrication. They are generally recycled within the industry itself for production of ingots. Availability of scrap plays a major role in the production of ingots. It strongly influences the amount and type of ingots produced at any given time. The scrap inventory of a smelter is determined by availability, storage capacity and operating capital. Since 75 percent of the cost of purchasing scrap is in direct payment to the seller, operators of smelters must maintain large amounts of liquid capital. This creates a significant economic burden for individual small plants. The price of scrap determines approximately 65 percent of the brass and bronze ingot market price (Arthur D. Little, 1976).

The cost of processing scrap before the actual ingot production step represents 40 percent of the total cost of production. This



Source: Arthur D. Little, 1976.

FIGURE 4-2
BRASS AND BRONZE ANNUAL INGOT PRODUCTION LEVELS
1965-1975

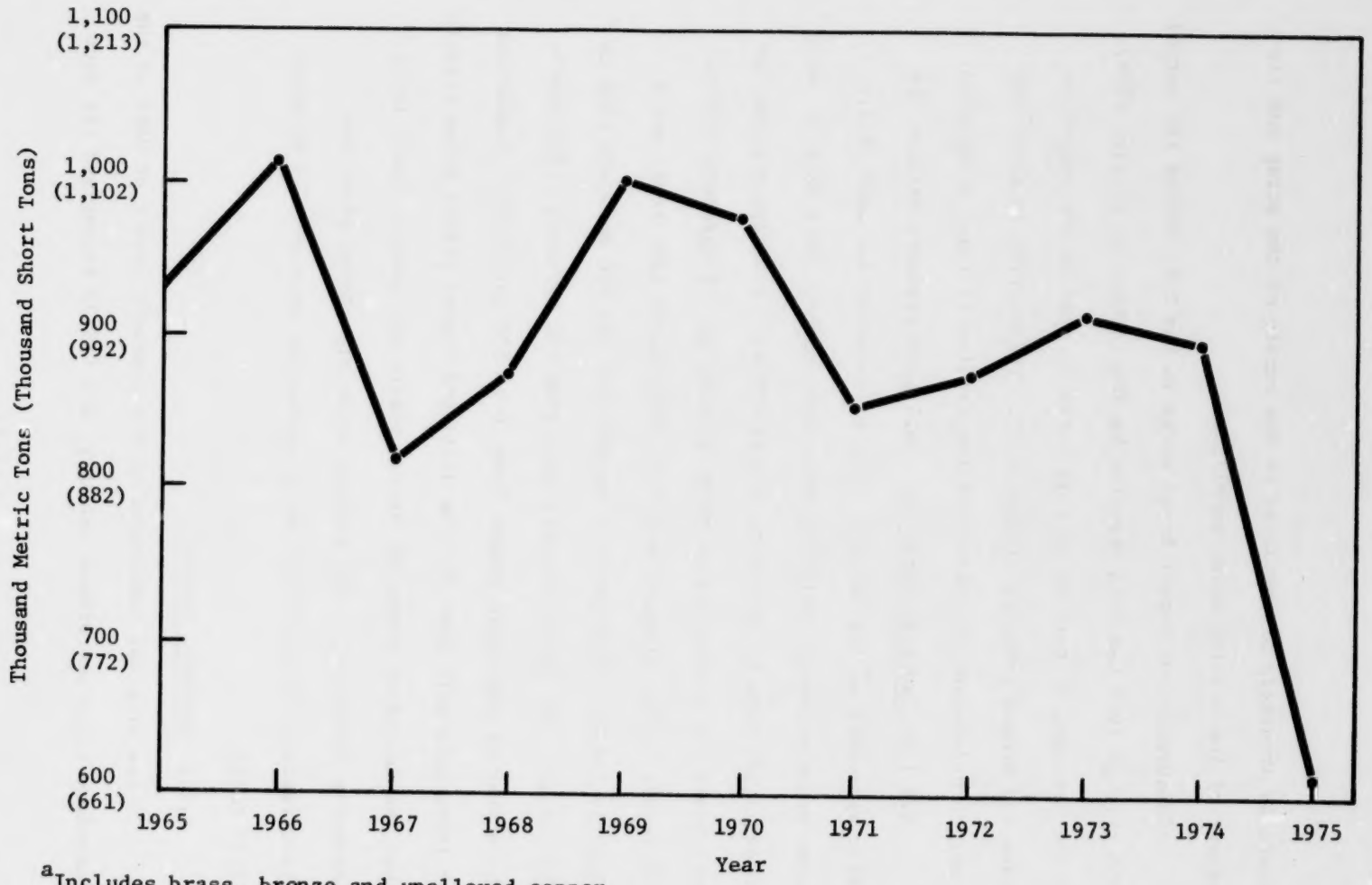
figure is inversely proportional to the purity of the scrap and its content of low boiling point metallics.

Consumption of copper based scrap in the U.S. during the period 1965 through 1975 has been reported by EPA (Arthur D. Little, 1976). On the average, 17 percent of this scrap is used in the secondary brass and bronze industry (Figure 4-3). The decline in scrap consumption understandably parallels the decline in ingot production.

4.1.1.3 Industry Capacity. Table 4-4 presents data on the basic structure of the secondary copper industry and each of its three major segments including brass and bronze. This data is based on estimates made by Arthur D. Little (1976). Production rates for most brass and bronze plants range from 90 to 450 Mg/month (100 to 500 tons). A few produce less than 90 Mg/month (100 tons) and a slightly larger number produce between 450 and 900 Mg/month (500 to 1000 tons). One plant produces more than 900 Mg/month (1000 tons). The number of employees ranges from 10 to 500 per plant. Comparison of these data with that for the unalloyed copper plants shows clearly that the secondary brass and bronze plants are usually small labor-intensive facilities. The average secondary copper plant has approximately 570 employees and a production rate of 5575 Mg/month (6145 tons).

4.1.2 Economic Outlook

In its original assessment of the economic impact of NSPS on the secondary brass and bronze industry, EPA (1973) recognized the fact



[a]Includes brass, bronze and unalloyed copper

Source: Arthur D. Little, 1976

FIGURE 4-3
ANNUAL COPPER-BASED SCRAP CONSUMPTION LEVELS[a]
1965-1975

TABLE 4-4

STRUCTURE OF SECONDARY COPPER INDUSTRY (1976)

Segment[a]	Plants		Employees		Production		
	Number	Percent of Industry	Number	Percent of Industry	Metric Tons/Month	(Short Tons/Month)	Percent of Industry
Brass/Bronze	37[b]	53	4,100	46	19,000	(21,000)	32
Copper	7	10	4,000	44	39,000	(43,000)	65
Other	26	37	900	10	1,800	(2,000)	3
Totals	70	100	9,000	100	59,800	(66,000)	100

[a]Brass/Bronze - Producers of brass and bronze ingots.
Copper - Producers of unalloyed copper at secondary smelters.
Other - Producers of secondary copper at primary smelters, refineries, fabricators, etc.

[b]The number of plants currently operating is 35 (Schroeder, 1978).

Source: Arthur D. Little, 1976.

that there were signs of a decline based on the fact that production reached a peak in 1965 and 1966 and has declined since then. Excess capacity exists in the industry and few, if any, new plants will be constructed in the future. Inspection of the data presented earlier in this section regarding number of plants, scrap consumption and ingot production rates clearly shows that the decline has been far greater than previously expected.

This decline may be attributed to two major reasons: the first is a decline in market demand for certain brass and bronze products, and the second is substitution of other materials or technologies for the previously used brass or bronze. Table 4-5 shows examples of both reduced usage and substitution (Monzon, 1978). In the future, new technologies such as fiber optics for telephone and data transmission may cause even further declines in brass and bronze demand.

The likelihood of the reversal of this decline was discussed with several key organizations associated with the industry:

- U.S. Bureau of Mines (Schroeder, 1978)
- Association of Brass and Bronze Ingot Manufacturers (Stafford, 1978)
- Joint Committee for Government Liaison of the Brass and Bronze Ingot Institute and the Association of Brass and Bronze Ingot Manufacturers (Maudlin, 1978).

All of these organizations are unquestionably convinced that the decline in brass and bronze ingot production and in the number of plants operating will continue into the foreseeable future.

TABLE 4-5

COMMONLY USED SUBSTITUTES FOR
COPPER, BRASS AND BRONZE

- Aluminum (electrical transmission, motor windings, light bulbs, construction)
- Iron and stainless steel (shell casings, construction, plumbing)
- Plastics (construction, plumbing, decorative items)
- Other (communications satellites, cryogenic superconductors)
- Reduced copper usage
    - Pulse code modulation increases communications capacity per unit mass of metal. In 1925 1 km of speech circuit used 85 kg copper. In 1975 only 0.17 kg was required.
    - Between 1945 and 1975 the amount of copper in the average automobile was reduced 50 percent.

Source: Monzon, 1978.

4.2 Brass and Bronze Ingot Production Process Description*

Brass and bronze ingot production is one of the three major parts of the industrial process, as shown in Figure 4-4. The raw materials used in ingot production are almost entirely derived from scrap materials with virgin metals used only to adjust the composition of the product as desired. These raw materials are subjected to a series of sorting, classification and preparation steps before undergoing the actual ingot production process. The ingots produced are generally further processed by remelting, shaping, rolling, extruding, etc. in brass or bronze mills to produce final products or intermediate products for delivery to brass and bronze manufacturing facilities.

The basic steps in the ingot production process are shown in Figure 4-5. There is some functional overlap between the raw materials collection and ingot production parts of the industry in the materials preparation steps, particularly the mechanical. Scrap dealers and brokers generally do some of the mechanical preparation since the value of the scrap is usually a function of its freedom from impurities and uniformity of composition.

4.2.1 Raw Materials

Scrap materials used in brass and bronze ingot production are usually gathered from one of three sources: "home," industrial or obsolete scrap. "Home" scrap refers to material recycled from ingot

*The material presented in Section 4.2 has been summarized in part from several references: Herrick, 1969; Jones, 1972; EPA, 1973a, 1977; and Arthur D. Little, 1976.

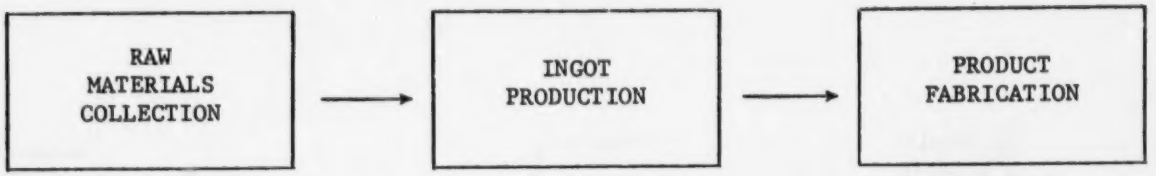


FIGURE 4-4
MAJOR PARTS OF THE BRASS AND BRONZE MANUFACTURING INDUSTRY

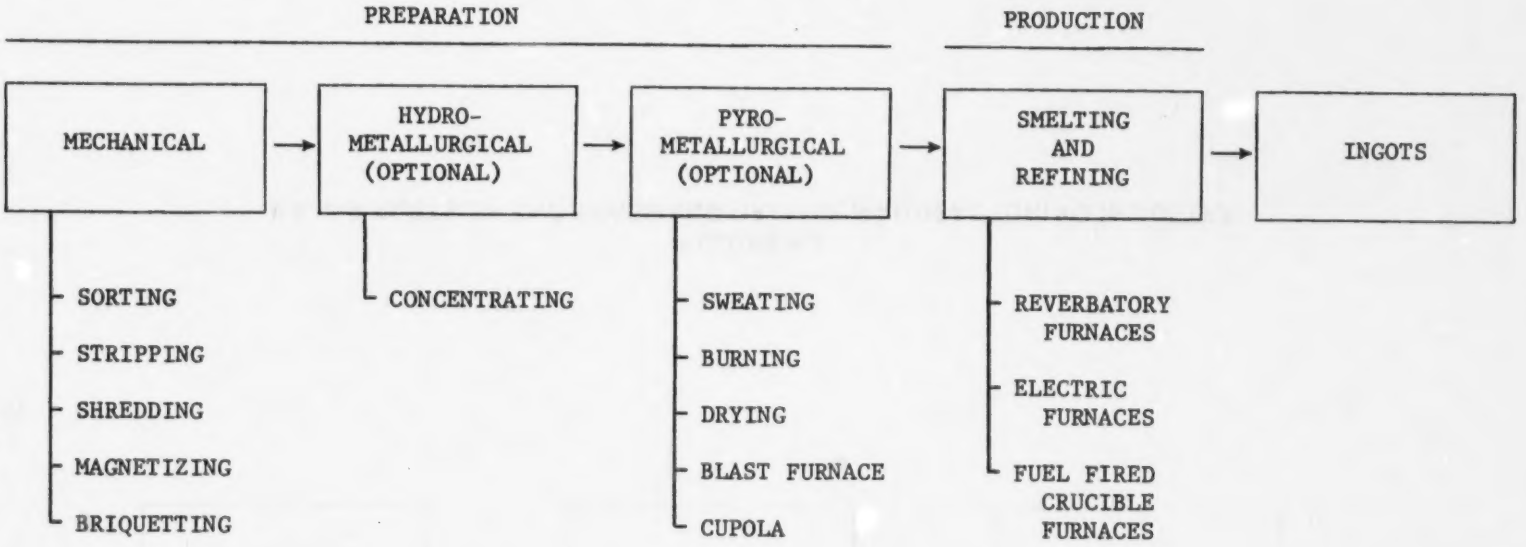


FIGURE 4-5
INGOT PRODUCTION PROCESS STEPS

producers and refiners. It is called "home" scrap because the material is recycled directly within the ingot production facilities. It consists of new alloys that are leftover after the production of desired castings, machinings or other materials.

Industrial scrap is essentially the same as "home" scrap except that it is recycled to ingot producers from outside sources. The recycling may be direct from source to ingot producer (captive industrial scrap) or indirect through scrap dealers or brokers (free industrial scrap). In either case the scrap is free of impurities and requires little preparation before charging into ingot production furnaces.

Obsolete scrap is composed principally of used materials being recycled through scrap dealers. This type of scrap usually contains significant amounts of undesirable materials such as oil, grease, paint, insulation and/or chemicals. This scrap requires much more preparation than the previous two types and has the potential for release of greater amounts of pollutants during the early steps of ingot production. Obsolete scrap may be quite uniform in composition as received, particularly if obtained in large quantities from specific industrial sources. However, it may also be extremely nonuniform if collected in small amounts or from diverse sources.

4.2.2 Materials Preparation

The basic purpose of the entire material preparation step, whether done by a scrap dealer or ingot producer, is to prepare a charge

for the ingot furnace that will produce the desired alloy ingot in the most cost-effective manner. This implies a twofold process: one is the removal of undesirable materials, both non-metallic and metallic; the other is obtaining a mixture of metals as close as possible to the composition of the desired product. This process avoids the necessity of removing and possibly losing valuable but unwanted metals or the necessity of adding virgin metals to adjust the alloy.

Ingot producers sometimes have the option of operating in one of two modes. They may choose only to purchase the type of scrap that best fits their current production needs, or they may alter their production to produce the type of alloy best suited to the scrap currently available. Obviously the market for ingots and availability of scrap have a great influence on these options.

4.2.2.1 Mechanical Preparation. Mechanical preparation of scrap generally involves some or all of the following steps:

1. Hand sorting
2. Stripping
3. Shredding
4. Magnetizing
5. Briquetting

Since brass and bronze scrap usually consists of large pieces rather than fine particles or dusts, the potential for air pollution during these steps is very low except for small particles of impurities produced during shredding. Briquetting generally has the

opposite effect of shredding due to the compactness of the material and subsequent ease of handling and charging to furnaces.

4.2.2.2 Hydrometallurgical Preparation. In this process, which is used occasionally, the difference in density of desirable and undesirable parts of the scrap provides the means for separation in a water medium. This method is most advantageously used for recovery of fine particle metallics not easily separated by one of the dry methods. Obviously, there is a potential for water pollution if this method is used.

4.2.2.3 Pyrometallurgical Preparation. The following methods all involve the use of heat in varying amounts for preliminary processing of brass and bronze scrap. The only methods covered under the present NSPS are use of the blast furnace or cupola.

1. Sweating
2. Burning
3. Drying
4. Blasting furnace
5. Cupola

Sweating furnaces are used primarily to remove valuable low-melting-point metals such as lead, solder and babbitt. If sufficient quantities of such metals are in the scrap, this is a profitable step. Furnace temperatures are kept relatively low to avoid loss of any of the desirable higher-melting-point alloys. This procedure is being used less and less due to the smaller quantities of such metals found with modern brass and bronze scrap.

Burning is used to remove insulation, wrappings and other specialized materials from the scrap which usually consists of wire. This process also may remove flammable oils, greases and the like from the scrap. This process obviously has a high potential for air pollution. In addition, some of the materials burned may release toxic substances. Common examples of controversial materials are fluorocarbons and polyvinyl chloride. Some ingot producers will not accept scrap from dealers if it contains substantial amounts of polyvinyl chloride.

Drying furnaces are used to vaporize substances such as cutting fluids from machine shop scrap. The temperature of this operation is critical since excessively high temperatures cause unwanted oxidation on the surface of the metal chips.

The terms blast furnace and cupola are often used interchangeably. However, the cupola is used to melt down metals or reduce metal oxides, while the blast furnace is used for reduction of metal oxides or smelting of virgin ores. These reducing operations cannot be done in reverberatory or refining furnaces due to the different composition of the interacting atmosphere. Coke is used as both a fuel and reducing agent. Such furnaces are also used to recover metal from skimmings and slags. The resulting product (black copper or cupola melt) is impure and must be refined in other furnaces to produce brass and bronze ingots.

A schematic of a blast furnace is shown in Figure 4-6. The blast furnace and cupola operate on a continuous feed basis with charge

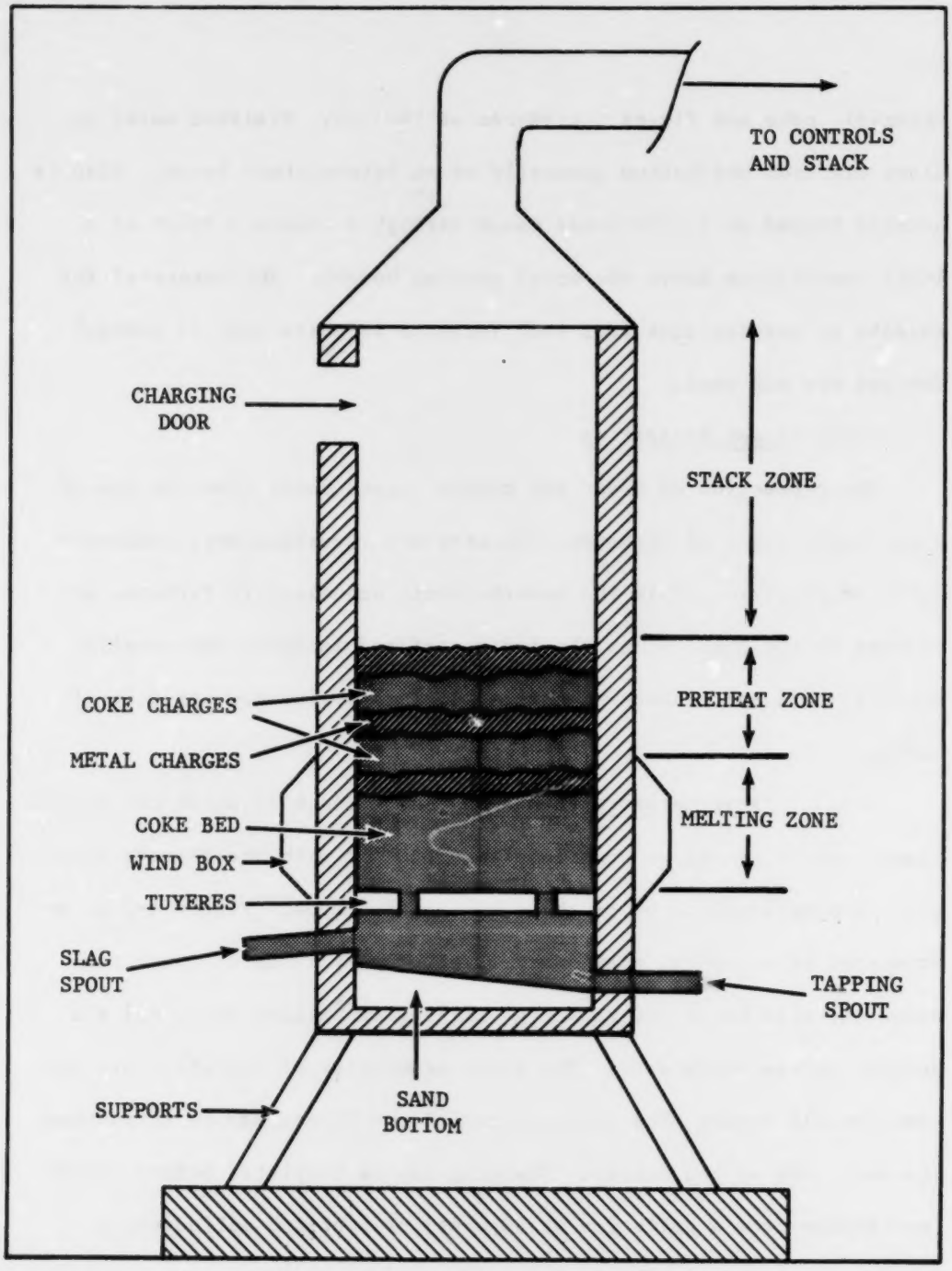


FIGURE 4-6
SCHEMATIC OF A TYPICAL SECONDARY METAL BLAST FURNACE OR CUPOLA

material, coke and fluxes introduced at the top. Finished metal is drawn off from the bottom generally on an intermittent basis. Slag is usually tapped on a continuous basis through a separate spout at a level immediately above the metal pouring height. The potential for release of particulates from such furnaces is quite high if control devices are not used.

4.2.3 Ingot Production

The production of brass and bronze ingots takes place in one of three basic types of furnaces, direct-fired reverberatory, indirect-fired or electric. Only the reverberatory and electric furnaces are covered by the NSPS, since the indirect-fired furnaces are usually small in size and produce significantly less pollutants per unit of charge.

4.2.3.1 Reverberatory Furnaces. Any furnace in which the burner flames and/or hot gases come in direct contact with the charged material is considered to be of the reverberatory type. Figure 4-7 is a schematic of a typical stationary reverberatory furnace. Such furnaces may also be of the rotating, rocking or tilting type, and all operate in the batch mode. The basic principles of operation are the same for all types. The charge material and fluxes may be introduced via end, side or top access. Charging may be completed before firing (preferable from a pollution standpoint) or continue periodically throughout the heat. The fuel burned is either oil or natural gas in combination with atmospheric or compressed air or, in special cases,

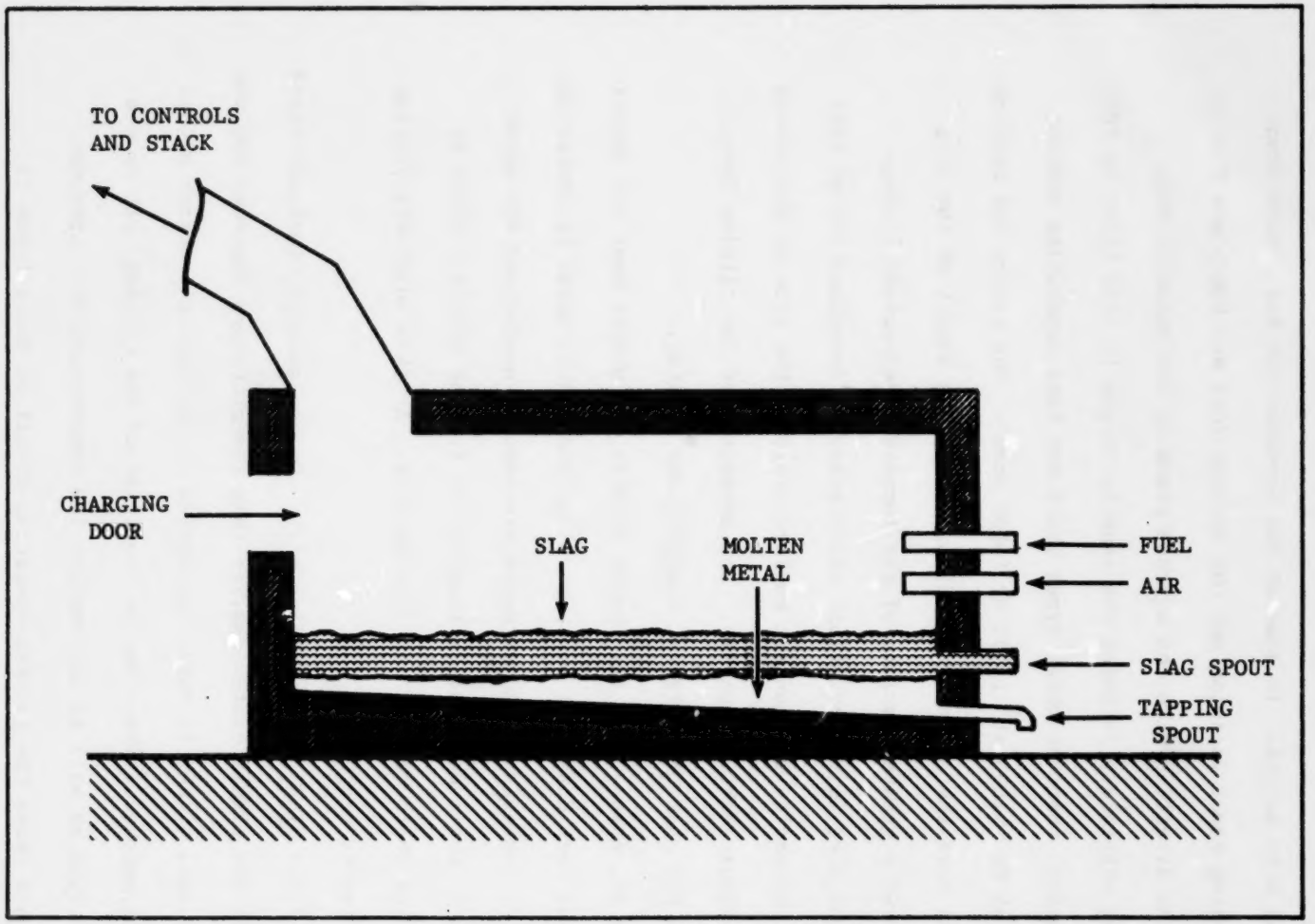


FIGURE 4-7
SCHEMATIC OF A TYPICAL STATIONARY REVERBERATORY FURNACE

enriched with oxygen. In some of the furnaces the bed slopes toward the tapping spout location and the burning fuel and hot gases flow in a counter direction with the exhaust stack on the opposite end.

The stationary furnaces are usually larger in size (100- to 200-Mg capacity) than the other types which may have capacities ranging from 0.45 Mg (∿1000 lb) to 90 Mg (∿100 tons). The rotary and rocking furnaces have the advantage of distributing the impact of the slag layer over a greater surface of the furnace's refractory lining. Since the slag is the principal contributor to deterioration of this lining, spreading the contact surface prolongs the life of the lining with obvious economic benefit. The advantage of the tilting furnace lies in the ease of charging, slagging and tapping.

In all cases, when the charge attains the proper heat and impurities have been drawn off into the slag, the molten metal is tested for its alloy composition. Adjustments are made as needed and the metal is brought to the ideal pouring temperature for the specific alloy by regulating the output of the fuel burners. At this point the pouring of the ingots begins.

4.2.3.2 Indirect-Fired Furnaces. On the average, indirect-fired furnaces are significantly smaller than reverberatory furnaces and are usually used either in small foundaries or for special purpose alloys in small batches. These may be crucibles of the tilting, pit or stationary type as well as the smaller low temperature pot furnaces. Figure 4-8 shows the general operation of all of these types of

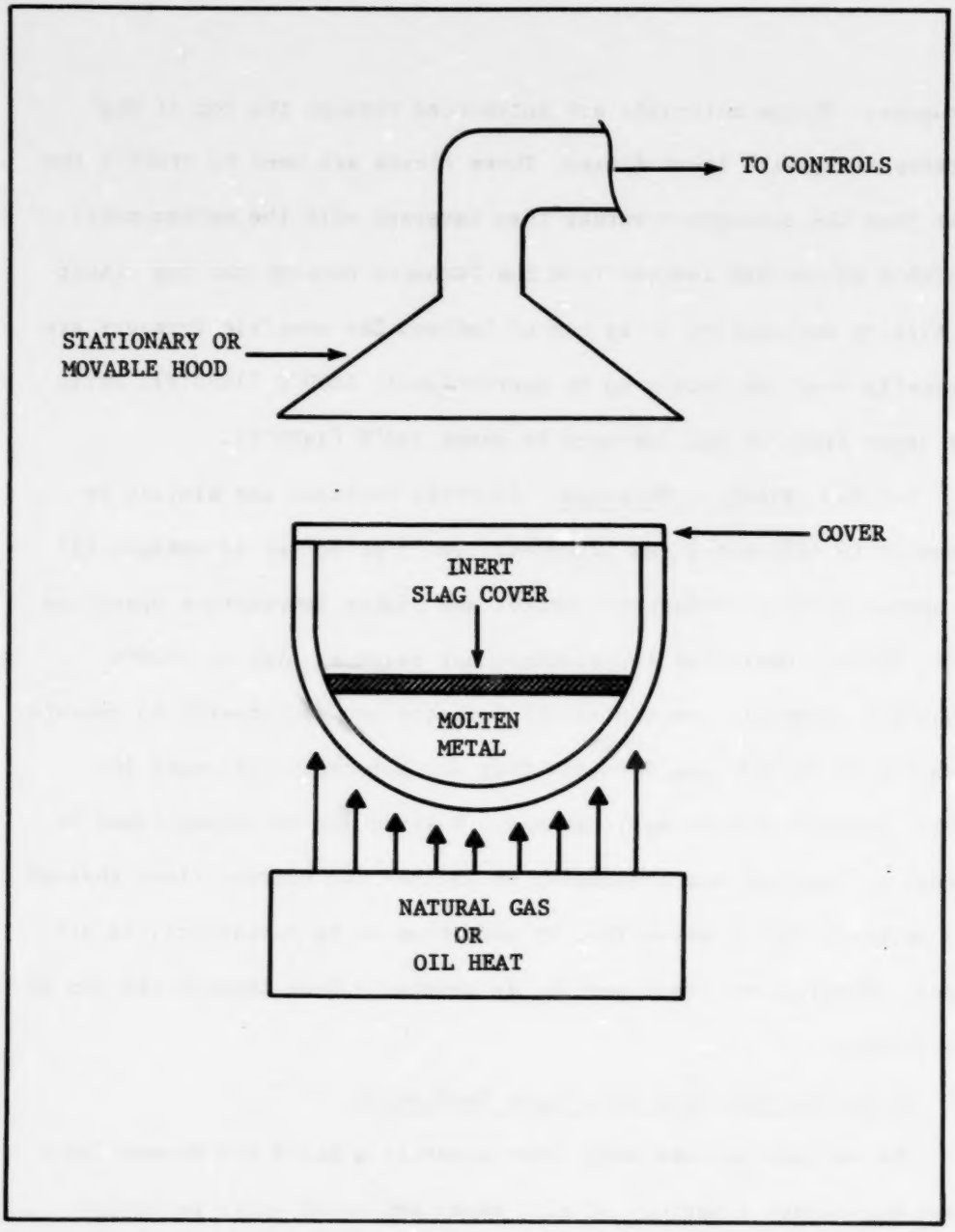


FIGURE 4-8
SCHEMATIC OF A TYPICAL INDIRECT-FIRED FURNACE

furnaces. Charge materials are introduced through the top of the furnace along with inert fluxes. These fluxes are used to protect the melt from the atmosphere rather than interact with the molten metal. Finished alloys are removed from the furnaces through the top either by tilting and pouring or by use of ladles. The crucible furnaces are generally used for metals up to approximately 1300°C (2400°F), while the upper limit of pot furnaces is about 760°C (1400°F).

4.2.3.3 Electric Furnaces. Electric furnaces are similar in function to indirect-fired furnaces. Their principal advantages lie in better furnace atmosphere control and higher temperature operation (EPA, 1973a). Operating temperatures may reach as high as 3300°C (6000°F). However, since electric furnaces are more costly to operate than oil or natural gas furnaces they are generally only used for small, special purpose applications. Heating may be accomplished by direct or indirect-arc (depending on whether the current flows through the molten metal or above it), by induction or by resistance. In all cases, charging and ingot pouring is generally done through the top of the furnace.

4.3 Pollution Potential from Ingot Production

The various process steps that occur at a brass and bronze ingot plant may create a variety of air, water and solid waste pollution problems. Table 4-6 summarizes the potential for such problems from each of the major process steps. The characteristics and extent of emissions to the air depend on the composition of the scrap and other

TABLE 4-6

POLLUTION POTENTIAL FROM INGOT PRODUCTION

	Preparation			Production
	Mechanical	Hydro-Metallurgical	Pyro-Metallurgical	Smelting and Refining
Stack Emissions	None	None	High	High
Fugitive Emissions	Low	None	High	High
Water Pollution	None	High	None*	None*
Solid Waste	Low	High	High	High

*Unless wet scrubber or water cooling used (not common).

charged materials, the fuel used, the desired temperature, the type of furnace, the desired alloy and various operating factors such as methods of charging, slagging, alloying and pouring ingots.

An estimate of the total particulate emissions after application of typical controls from various pyrometallurgical and smelting steps has been given for the year 1968 (Midwest Research Institute, 1971). These figures are shown in Table 4-7 along with MITRE projections for 1975. These projections were based on a comparison of 1968 and 1975 brass and bronze ingot production levels as given by EPA (Arthur D. Little, 1976). These figures are obviously small compared with the total U.S. particulate emissions of 17.7×10^6 Mg (19.5×10^6 tons) for 1974 (Council of Environmental Quality, 1975).

4.3.1 Pollution from Mechanical and Hydrometallurgical Preparation

Raw materials handling and mechanical preparation of scrap has a very low potential for emission of air pollutants. Most of the scrap is in the form of pipes, chunks, castings and the like which are unlikely to cause problems. Smaller scrap containing borings, chips and grindings is usually coated with cutting oils which greatly reduces the likelihood of dust or particulate emissions. When dry slags are recycled there may be some fugitive dust; but it is judged to be of minor impact (Herrick, 1969).

Hydrometallurgical processes have a high potential for water pollution if the discarding of used water is not carefully controlled. In addition, disposal of other wastes may create a solid waste

TABLE 4-7

ESTIMATED PARTICULATE EMISSIONS FROM INGOT PRODUCTION

Process Step	Emissions After Typical Controls (Mg/yr (tons/yr)	
	1968	1975
Wire Burning	11,800 (13,000)[a]	7,250 (8,000)
Sweating Furnace	113 (125)	68 (75)
Blast Furnace	680 (750)	408 (450)
Smelting Furnace	4,990 (5,500)	3,000 (3,300)
Totals	17,583 (19,375)	10,726 (11,825)

[a]MITRE Projections.

Source: Midwest Research Institute, 1971.

problem. However there is no potential for air pollutants from any of the hydrometallurgical processes.

4.3.2 Pollution from Pyrometallurgical Preparation

Pyrometallurgical preparation of scrap releases the greatest amount of particulate matter of any of the secondary brass and bronze production procedures. As can be seen from Table 4-7, 72 percent of the emissions are from pyrometallurgical processes. After allowance for blast furnaces, which are regulated by NSPS, the remainder from wire burning and sweating furnaces still constitutes the major fraction of particulate emissions (68 percent of the total brass and bronze emissions).

During wire burning the major portion of the emissions will come from the insulation on the wire and the accompanying oils and greases (Herrick, 1969). Source tests conducted in Los Angeles have shown uncontrolled emissions as high as 6.6×10^4 mg/dscm (29 grains/dscf) (EPA, 1973). This constitutes the largest single source of particulates in the entire brass and bronze industry. In addition, the emissions may contain significant amounts of hazardous and/or toxic substances such as reactive hydrocarbons, fluorides and the combustion products of common polymers such as polyvinylchloride.

Sweating furnaces operate at fairly low temperatures so that the metal fume losses are very low. Due to the nature of the scrap, fumes and combustion products of antifreeze residues, soldering salts and hose connections are likely to be emitted (Herrick, 1969). This will

be in addition to the expected oils and greases associated with such material.

When drying furnaces are used to remove cutting oils from chips and borings, a potential for hydrocarbon emissions exists. Unless combustion in the furnace is complete enough to produce inert emission products, controls such as afterburners may have to be considered.

Fumes and dust from blast furnaces and cupolas are basically similar to that from the ingot furnaces. However, since blast furnaces and cupolas are generally used to concentrate low-grade scrap, slag and skimmings, the ratio of nonmetallic particles to metallic fumes is considerably higher. Since the nature of the feed material is likely to be quite variable, this ratio will vary as well as the total quantity of the emissions. Herrick (1969) reports uncontrolled emissions ranging from 16 kg (35 lb)/hr to 100 kg (220 lb)/hr from three blast furnaces of unspecified size.

4.3.3 Pollution from Smelting and Refining

Direct-fired furnaces of the reverberatory and rotary type will produce larger quantities of metallic fumes such as zinc oxide and lead oxide than the indirect-fired furnaces. This is due to the impingment of the hot burner flames and gases directly on the charge resulting in the vaporization of larger quantities of the lower boiling point metals. According to EPA (1973) other factors causing relatively large fume concentrations are:

- Alloy composition -the rate of loss of zinc is approximately proportional to the zinc concentration in the alloy.

- Pouring temperature - an increase of 55°C (∿100°F) in pouring temperature increases the rate of loss of zinc about three times.

- Poor foundry practice - improper combustion, charging at maximum temperature, heating the charge too fast and insufficient flux cover will all contribute to excessive emissions.

The concentration and characteristics of the emissions will vary as a function of both the fuel (energy) used and the stage of the ingot production cycle. Electric furnaces have no emissions that are due to the type of energy used. Fuel-fired furnaces may or may not have emissions based on the fuel used. The choice of fuel is usually made on the basis of the lowest projected cost at the time of furnace construction. Some facilities may have combination burners that allow switching between natural gas and fuel oil based on current availability and cost. Natural gas is essentially pollution-free, but fuel oils may cause some emissions. If combustion practices are not carefully controlled, these fuels may emit soot, smoke and unburned hydrocarbons. The likelihood of significant amounts of sulfur emissions is quite small since number two fuel oil is generally low in sulfur content and in addition, the presence of sulfur is undesirable in any copper metal or alloy production. The producers try to obtain the lowest possible sulfur content fuel. Table 4-8 presents gaseous emissions from a typical oil-fired brass and bronze reverberatory furnace (Hardison and Herington, 1970). The data show that except for a small amount of carbon monoxide, no significant amounts of any gaseous pollutants are released. Data obviously represent gaseous emissions from

TABLE 4-8

GASEOUS EMISSIONS FROM A TYPICAL OIL FIRED BRASS/BRONZE REVERBERATORY FURNACE (60 TON FURNACE, WATER SPRAYS, U-TUBE COOLER, FABRIC FILTER)

Species	Composition
O_2	18-19% Weight
CO_2	0.6-0.9% Weight
CO	20-23 ppm
SO_2	<1 ppm
NO_2	<1 ppm
H_2S	<1 ppm
Hydrocarbons	<<1 ppm
Halogens	<1 ppm
N_2, H_2O, Inerts	Remainder

Source: Hardison and Herington, 1970.

both the fuel burned and from the charged materials. It can be seen that emissions of fluorides (halogens) and reactive hydrocarbons are very small as opposed to the high potential for such emissions during wire burning and other pyrometallurgical preparation.

As stated previously, the potential for particulate emissions both primary (through the stack) and secondary (fugitive) varies with the stage of the production cycle, which may be divided into five parts: charging, melting, refining, alloying and pouring.

In general, the ratio of metallic fumes to other particulate substances in the emissions will increase as the production cycle proceeds. This is due to the constant elimination of the impurities in the charge which account for the bulk of the nonmetallic particulates. The exception to this is the possibility that some of the nonmetallic particulates may be emitted from the various fluxes added to the furnace.

Table 4-9 shows the chemical composition of dust recovered from a fabric filter used on a brass and bronze furnace.

TABLE 4-9

CHEMICAL ANALYSIS OF BRASS AND BRONZE BAGHOUSE DUST

Substance	Composition (% Weight)
Zinc	45-77
Lead	1-12
Tin	0.3-2
Copper	0.05-1
Chlorine	0.5-1.5
Sulfur	0.1-0.7
Remainder (oxygen as oxide, etc.)	5.8-53

Source: Herrick, 1969.

Zinc, generally in the form of zinc oxide, predominates the dust. Table 4-10 shows the melting and boiling temperatures of various metals along with the preferred metallurgical pouring temperature for copper and several common categories of brasses and bronze. The data show that zinc has the lowest boiling point (907°C/1665°F) of any of the metals commonly found in the furnace charge. In addition, this temperature is several hundred degrees lower than the pouring temperature of copper and most of the brasses and bronzes.

Particle size ranges for brass and bronze metallic fumes and oxides have been reported in several references (Herrick, 1969; Midwest Research Institute, 1971; EPA, 1973). Minimum size was consistently reported as 0.03 m with maximum size ranging from 0.3 to 0.5 μm.

4.3.3.1 Emissions During Charging. The quantity and type of emissions released during furnace charging are quite variable. The principal factors which cause this variation are:

- Metallic composition of the scrap
- Quantity and type of oils, greases and other impurities in the scrap
- Location of the charging doors
- Extent of time required to complete the charge
- Burner settings during charging.

Scrap charges with high zinc content and/or high volatile or combustible impurity content will produce greater amounts of both stack and fugitive emissions during charging. The location of charging

TABLE 4-10

MELTING, BOILING AND POURING TEMPERATURES OF METALS AND ALLOYS

Substance	Melting Temperature °C	(°F)	Boiling Temperature °C	(°F)	Approximate Pouring Temp. °C	(°F)	Reference
Mercury	-39	(-38)	357	(675)			a
Arsenic	817(1503)(28 atm.)		613(1135)(sublimes)				a
Aluminum Brass					730	(1346)	b
Magnesium Brass					760	(1400)	b
Cadmium	321	(610)	765	(1409)			a
Zinc	419	(786)	907	(1665)			a
Magnesium	651	(1204)	1107	(2025)			a
Barium	725	(1337)	1140	(2084)			a
Copper	1083	(1981)	2595	(4703)	1100-1200	(2000-2200)	a, c
Bronze					1100-1200	(2000-2200)	c
High Zinc Brass					1150(2100)		b
High Lead Brass					1200(2200)		b
High Nickel Brass					1300-1325	(2375-2425)	b
Antimony	631	(1168)	1380	(2516)			a
Bismuth	271	(520)	1560	(2840)			a
Lead	328	(622)	1744	(3171)			a
Tin	232	(450)	2270	(4118)			a
Aluminum	660	(1220)	2467	(4473)			a
Chromium	1890	(3434)	2482	(4500)			a
Boron	2300	(4172)	2550	(4622)			a
Nickel	1453	(2647)	2732	(4950)			a
Cobalt	1495	(2723)	2900	(5252)			a
Manganese	1244	(2271)	2907	(5265)			a
Beryllium	1278	(2332)	2970	(5378)			a
Iron	1535	(2795)	3000	(5432)			a
Molybdenum	2610	(4730)	5560	(10040)			a
Tungsten	3410	(6170)	5927	(10701)			a

[a]Handbook of Chemistry and Physics, 1975.
[b]EPA, 1977.
[c]EPA, 1973a.

doors also plays a key role. Overhead doors permit much larger losses of gas, ash and fume into uncontrolled areas around the furnace. This is particularly true when charging is done at intervals allowing cool scrap and impurities to contact the already molten metal in the furnace. It is usually difficult to place the entire charge into the furnace at one time, thus necessitating interval charging to some extent. The emissions can be reduced somewhat if burners are turned off or lowered during charging, particularly if the scrap is known to be very oily.

4.3.3.2 Emissions During Melting. After charging is completed, the furnace is closed and emissions are released only through the normal flue and stack system. This period of rapid maximum heating releases large quantities of metal fume and the end products of combustible impurities. Some control over the release of the latter can be exercised by proper air and burner settings, but the primary objective is rapid melting of the scrap.

4.3.3.3 Emissions During Refining. Refining is that step in the process during which all remaining impurities and other constituents in excess of specifications are removed or chemically reduced. Refining methods vary depending on the type of furnace, composition of the scrap and the desired alloy, but the basic approach is the same for all. Depending on the above factors, various fluxes such as solids, liquids and gases are used in refining. Compressed air is the most extensively used flux. Blowing air into the molten metal causes

selective oxidation of metals in accordance with their position in the electromotive series. The air blowing also oxidizes the remaining impurities. The metal oxides are entrapped in the slag covering or entrained in the furnace exhaust gases. In some cases nitrogen is used to remove entrained gases, oxides of impurities, or to mechanically and buoyantly lift foreign matter out of the metal bath. During this entire process part of the zinc is unavoidably oxidized and removed along with the impurities, thus leading to the high zinc content of the emissions.

In general, the types of solid or liquid fluxes used do not contribute to air pollution. Rather, they are beneficial since they prevent excessive metal volatilization and serve as a collector for most of the impurities.

4.3.3.4 Emissions During Alloying. Alloying is the step during which the molten metal is adjusted to the desired alloy composition by addition of special scrap or virgin metals. Since ingot producers prefer to achieve the desired alloy by initial charging with the proper type of scrap, this step is employed as little as possible. Since additional materials are added through charging doors, emissions of fugitive metallic fumes are quite likely. The quantity of fumes emitted depends to a great extent on the percentage of zinc in the desired alloy.

4.3.3.5 Emissions During Pouring. Methods of pouring the ingots vary but significant commonality exists. In all cases the alloyed

metal is brought to a preferred pouring temperature specific to the particular alloy. Slag covers are used on any transfer vessels such as ladles especially for high-zinc alloys. However, during actual pouring large quantities of metal fumes are emitted. After pouring, the ingot molds are usually covered with some material such as charcoal to prevent metal oxidation and to produce smooth ingots. The application of the charcoal generally produces a shower of hot particulates which are largely uncontrolled. All of the methods used for pouring ingots are extremely difficult to control adequately since the hooding of movable equipment can be quite complex. This difficulty was recognized during the previous background study of NSPS for secondary brass and bronze and was acknowledged by the fact that the pouring cycle is exempt from the particulate testing procedure for reverberatory furnaces.

4.4 Control Technology Applicable to Brass and Bronze Furnaces

The control of particulates and the reduction of opacity at brass and bronze ingot production plants is in reality a single problem. It is generally acknowledged that for most industrial processes good control of particulates will automatically result in low plume opacities. A report on the stack exit mass loadings which would yield no visible emissions from various industrial processes (Beach, 1973) shows that for zinc fume from a zinc smelter melting operation using a fabric filter control, a stack exit emission level of 22.8 mg/actual cubic meter (acm) or 0.010 grains/actual cubic foot (acf) at 204°C (400°F)

should result in no visible emissions. Converting this value to standard conditions yields 36.5 mg/standard cubic meters (scm) or 0.016 grains/standard cubic feet (scf) at 20°C (68°F). From a copper reverberatory furnace equipped with a fabric filter, these values are 34.2 mg/acm (0.015 grains/acf) at 288°C (550°F) or 65.5 mg/scm (0.029 grains/scf) at 20°C (68°F). These data indicate that any brass and bronze furnace emissions (which are similar in many ways to the zinc and copper emissions) that are controlled to the NSPS level of 50 mg/dry standard cubic meters (0.022 gr/dscf) would probably have very low or no visible emissions. Based on the above reasoning, the following paragraphs will discuss particulate control techniques only from the standpoint of their ability to reduce particulate grain loadings and not to eliminate or reduce visible emissions. The latter will be taken for granted.

4.4.1 Fine Particulate Control Technology

There are five basic types of control equipment for removal of suspended particulates from airstreams:

1. Settling chambers
2. Cyclones or centrifugal collectors
3. Scrubbers
4. Electrostatic precipitators (ESP)
5. Baghouses

Since almost all of the particles from brass and bronze furnaces are less than 0.5 μm, settling chambers and cyclones are of practically no value in control. Such devices are designed for use where minimum particle sizes are at least an order of magnitude larger (Midwest Research Institute, 1971; Duncan et al., 1973; Caplan, 1977). Thus, such devices are limited to control of coarse particulates only or for separation of coarse particulates from an airstream prior to entry into other types of control equipment.

Past experience has shown that wet scrubbers and ESPs have not been very successful in controlling metallic fumes such as zinc oxide when compared with fabric filters (Herrick, 1969; Squires, 1974; Drehmel, 1977). High pressure drop venturi scrubbers are used to some extent in the brass and bronze industry, but their overall control efficiency is significantly lower than that of the fabric filters (Jones, 1972). Three scrubbers serving brass furnaces have reported efficiencies between 53 and 65 percent (EPA, 1977). These values are far below what would be required for adequate control under the current NSPS.

Electrostatic precipitators have not been used in the industry mainly due to two factors. Such devices are not common on gas flows below 550 scmm (20,000 scfm) (EPA, 1977). In addition, the efficiency of collection of metallic fume is reduced due to the high resistivity of such particles (Jones, 1972).

The fabric filter is the device most often selected by the industry. Fortunately it works well on the fine particulates produced by brass and bronze furnaces. According to EPA (1977), the principal control device used for particulate control from brass and bronze furnaces and cupolas is the fabric filter. A survey made by EPA (1977) of all the member companies of the Brass and Bronze Ingot Institute shows that out of 57 reverberatory or electric furnaces with capacities of 1 ton or greater, 36 used fabric filter controls while the remainder were uncontrolled. Of the six cupola furnaces, four used fabric filter controls, one used a wet scrubber and one was uncontrolled.

The fabric filter will most likely continue to be the best choice for control of fine particulates. A comprehensive review of the control of particulates from nonferrous metal furnaces was given by Squires (1974) in a report on the efficiencies of collection of various sizes of particulates for a full range of control devices. Table 4-11 lists these data and shows fabric filters as the most effective devices at all size ranges.

In a recent comprehensive study of fine particle control technology (Drehmel, 1977) three conclusions were presented:

1. Electrostatic precipitation can achieve a minimum efficiency of 90 percent under appropriate resistivity of the particles.
2. Fabric filters will provide greater than 95 percent efficiency at all particle sizes.
3. New devices may be applicable mostly in special circumstances.

TABLE 4-11

GAS CLEANING EQUIPMENT PERFORMANCE FOR NONFERROUS METAL FURNACES

Collector	Approximate Efficiency (%)			
	Standard Dust 80%>60 μm	At 10 μm	At 5 μm	At 1 μm
Low-Pressure Cellular	74.2	62	42	10
High-Efficiency Cylcones	84.2	85	67	10
Small Multicyclones	93.8	96	89	20
Self Induced Spray	93.5	97	93	32
Spray Tower	96.3	96	94	35
Dry ESP	94.1	98	92	82
Wet Impingement Scrubber	97.9	99	97	88
Wet ESP	99	99	98	92
High-Pressure Drop Venturi Scrubber	99.7	99.8	99.6	94
Fabric Filter	99.8	99.9	99.9	99
Precoated Fabric Filters	>99.9	>99.9	>99.9	>99.9

Source: Squires, B.J. 1974.

Table 4-12 presents efficiency versus particle size for specific collectors and applications reported in the study. The data indicate two points; first, that fabric filters have the highest overall efficiencies and, second, there is a minimum in collection efficiency in the sizes around 0.5 m for most control devices, particularly the ESP. However, for fabric filters the difference between this minimum and the overall efficiency is almost negligible. This is a very important consideration in control of metallic fume since most of the particles are in the 0.5-μm range.

4.4.2 Cost of Control Devices

An important consideration in the selection of the best control device is the cost associated with both the installation and operation. The efficiencies of many types of controls can be increased by appropriate changes in design parameters. However, these changes are usually accompanied by significantly higher costs.

To compare the probable capital costs of three types of control devices applied to brass and bronze furnaces, typical costs were calculated on the assumption that they would be used on the recently opened plant of the American Brass Company in Headland, Alabama. This plant is the only one that has become operational since the promulgation of the NSPS. Operational data were obtained (Alabama Air Pollution Control Commission, 1978) and used to calculate the approximate capital costs of a dry ESP, a high pressure drop scrubber and a fiberglass fabric filter system. Results are given in Table 4-13. These

TABLE 4-12

RECENT DATA ON FINE PARTICULATE CONTROL DEVICES

Collector and Application	Collection Efficiency (%)								
	10 μm	2 μm	1 μm	0.7 μm	0.6 μm	0.5 μm	0.4 μm	0.3 μm	0.1 μm
ESP (Power Plant)	99.9		95			90			99
Hot-ESP (Cement)	>98		>98			90			>98
Mobile Bed (TCA) Scrubber (Power Plant)				80			30		97
Teflon Coated Glass Fabric (Power Plant)			99			98			99
Graphite Coated Glass Fabric (Power Plant)			99			99			99
Nomex (Industrial Boiler)		98			95				99
Orlon (Lead Sintering)		99.6		99.4				99.5	

Source: Drehmel, D.C., 1977.

TABLE 4-13

APPROXIMATE COST OF TYPICAL CONTROL EQUIPMENT
(DECEMBER 1977 DOLLARS)

Control Equipment	Total Installed Cost[a]
$1134 m^3 min^{-1}$ (40,000 cfm) Dry Insulated ESP; $2322 m^2$ (25,000 sq. ft.) Plate Area (Uninsulated cost in parentheses)	$220,000 ($170,000)
$1134 m^3 min^{-1}$ (40,000 cfm) 3/16 in. thickness, No. 304 Stainless Steel Scrubber: Pressure Drop: 50 to 125 cm (20 to 50 in.)	$ 72,000
$1134 m^3 min^{-1}$ (40,000 cfm) Fiberglass Fabric Filter; Air/Cloth 2.5/1; Stainless Steel, Continuous Pressure Suction Operated with Mechanical Shakers	$110,000

[a]Calculations based on information given by Neveril, R.B. et al. (1978).

calculations were based on the approach used by Neveril et al. (1978). An overall efficiency of 99 percent was assumed for the ESP. Additional calculations based on an efficiency of 99.9 percent raised the required collector plate area to 3530 m^2 (38,000 ft^2). This in turn raised capital costs to $200,000 for an uninsulated unit and $300,000 for an insulated one.

Additional calculations for scrubbers show that for a pressure drop of less than 50 cm (20 in.) the cost lowers to about $55,000. Increasing the pressure drop to the range of 125 to 250 cm (50 to 100 in.) raises the cost to about $94,000.

Calculations for the fabric filter system were based on an air-to-cloth ratio of 2.5:1, which is typical for brass and bronze furnaces (Herrick, 1969). The costs shown include the initial set of fiberglass bags. The cost of the bags could be as much as 2.5 times higher if materials such as Nomex were used (Neveril et al., 1978). This would increase the cost of the total system by $14,000 and obviously increase the cost of bag replacement.

In a comprehensive study of the control of fine particulates (Midwest Research Institute, 1970), extensive data were obtained on operating costs of typical control devices. This information was used to estimate the annual operating cost, including maintenance, for fabric filters, scrubbers and ESPs. Table 4-14 presents these data adjusted to 1977 dollars. Also given are annual capital costs of controls on a 7-year depreciation basis and an estimate of the possible

TABLE 4-14

ESTIMATE OF ANNUAL CAPITAL AND OPERATING COSTS OF VARIOUS CONTROL DEVICES IF INSTALLED AT A TYPICAL SECONDARY BRASS AND BRONZE SMELTER (1977 DOLLARS)

	High Efficiency Scrubber		High Efficiency ESP		High Temperature Fabric Filters	
	Annual Cost	% of Gross Sales[a]	Annual Cost	% of Gross Sales[a]	Annual Cost	% of Gross Sales[a]
Capital Cost of Controls (7 yr depreciation)	10,500	0.09	31,500	0.3	15,700	0.1
Operating Costs of Controls[b]	84,700	0.7	26,180	0.2	24,640	0.2
Total	95,200	0.8	57,680	0.5	40,340	0.3

[a]Gross sales based on annual production of 5500t (6063 tons) selling at $2.16 per kg ($0.98 per lb) = $11,880,000

[b]Based on data from Midwest Research Institute, 1970.

annual gross sales price of brass ingots based on a linear projection of the current American Brass operating schedule. The cost of brass ingots is based on projections of the cost of brass and bronze ingots given by Arthur D. Little (1976). These data show that the impact of control costs on the overall industry is quite small.

5.0 ANALYSIS OF POSSIBLE REVISIONS TO THE STANDARDS

5.1 Availability of Test Data

The Metrek Division of The MITRE Corporation conducted a survey of the 10 EPA regions to determine the number and location of new or modified facilities for 10 industrial categories subject to NSPS (Watson et al., 1978). Included in the survey was the secondary brass and bronze ingot industry. The survey also gathered all available NSPS compliance test data for the industries and solicited the opinions of regional personnel regarding all facets of the NSPS program. At that time (November 1977 through January 1978) none of the regions was aware of any new, modified or planned secondary brass and bronze facilities. In addition, no one voiced any opinion about the current NSPS.

Recently a survey was made of other organizations with possible awareness of the brass and bronze industry to determine if they knew of any new, modified or planned facilities. This survey included:

- U.S. Bureau of Mines (Schroeder, 1978)
- Effluent Guidelines Division, EPA (Williams, 1978)
- Association of Brass and Bronze Ingot Manufacturers (Stafford, 1978)
- Joint Committee for Government Liaison of the Brass and Bronze Ingot Institute and the Association of Brass and Bronze Ingot Manufacturers (Maudlin, 1978).

This latter survey identified the existence of one new smelter, American Brass Inc. of Headland, Alabama.

Administrative data for the plant are presented in Table 5-1 (Sherman, 1978; Alabama Air Pollution Control Commission, 1978). In addition, the Alabama Air Pollution Control Commission provided a copy of the results of the NSPS Compliance Test which was made on the smelter in February of 1978. These data are shown in Table 5-2. It is important to note that change of plant ownership does not constitute an NSPS change or modification and in no way affects the validity or applicability of the test results.

To assess this single set of test data, results of tests at other facilities prior to promulgation of the current NSPS were gathered (Table 5-3). The American Brass average value of 16.9 mg/dscm (0.0074 grains/dscf) is lower than most of the previous test data but is not a sufficient basis to draw any overall conclusion about improved control technology for brass and bronze furnaces.

5.2 Indication of the Need for a Revised Standard

5.2.1 Current Standard

At this time, there is not sufficient justification for revision of the present NSPS for reverberatory, blast or electric furnaces. This applies to both the particulate and opacity standards. These statements are based on the following considerations:

- Although there have been constant minor improvements in many types of control technology in recent years, the fabric filter still remains the most practical and effective device.
- There have been no technology breakthroughs that would provide major improvement in current fabric filter technology.

TABLE 5-1

ADMINISTRATIVE DATA FOR AMERICAN
BRASS INC. SMELTER

Present Ownership:	American Brass Inc. Box 185 Headland, Alabama 36345
Operational Dates:	31 August 1978 to present
Parent Corporation:	Commercial Technology, Inc. 3530 Forest Lane, Suite 98 Dallas, Texas 75234
Previous Ownership:	Sitkin Smelting and Refining, Inc. Dothan, Alabama
Operational Dates:	19 May 1977 to approximately 15 July 1978
Previous Parent Corporation:	Sitkin Smelting and Refining, Inc. Box 708 Lewistown, Pennsylvania 17044

Sources: Sherman, G., 1978; Alabama Air Pollution Control Commission, 1978.

TABLE 5-2

NSPS COMPLIANCE TEST RESULTS FOR
AMERICAN BRASS, INC.

1. Date of Compliance Test: February 20, 1978

2. Furnaces: Four rotary reverberatory melting furnaces manufactured by the Posey Iron Works; three with 40 Mg (44 tons) capacity each and one with 10 Mg (11 tons).

3. Control Equipment: Lear-Siegler/Luhr Fabric Filter, Model EKD, Model No. 6/2x98 (two houses)

4. Compliance Test Results:
   Measured: Run 1 - 24.9 mg/dscm at 1128 dscm/min
   (0.0109 grains/dscf at 39,835 dscf/min)

   Run 2 - 17.8 mg/dscm at 1096 dscm/min
   (0.0078 grains/dscf at 38,719 dscf/min)

   Run 3 - 8.0 mg/dscm at 1184 dscm/min
   (0.0035 grains/dscf at 41,818 dscf/min)

   Average - 16.9 mg/dscm (0.0074 grains/dscf)

   Allowable: 50 mg/dscm (0.022 grains/dscf)

   Six-minute average visible emissions: 5%

5. Operational Data:
   During Test: All four furnaces operating
   Normal: Two or three furnaces operating
   Current: One 40 Mg (44 ton) furnace, 2 to 3 days per week

Source: Alabama Air Pollution Control Commission, 1978.

TABLE 5-3

PREVIOUS PARTICULATE TEST DATA

Source of Data		Capacity Mg (Tons)	Average Grain Loading mg/dscm (grains/sdcf)
EPA[b]	Gas Rotary Reverb.	6.8 (7.5)	5.5 (0.0024)
EPA[b]	Gas Stationary Reverb.	90.7 (100)	25 (0.011)
EPA[b]	Gas Stationary Reverb.	54.4 (60)	32 (0.014)
EPA[b]	Oil Rotary Reverb.	18.1 (20)	25 (0.011)
EPA[b]	Gas Stationary Reverb.	90.7 (100)	32 (0.014)
EPA[b]	Gas Rotary Reverb.	15.9 (17.5)	14 (0.006)
EPA[b]	Two Rotary Reverb.	49.9 (55) Total	39 (0.017)
EPA[b]	Two Rotary Reverb.	24.9 (27.5) Total	27 (0.012)
EPA[b]	One Rotary Reverb. One Rotary Reverb. One Blast Furnace	6.8 (7.5) 15.9 (17.5 -	39 (0.017)
EPA[a]	One Blast Furnace	-	30 (0.013)
GCI[c]	Two Stationary Reverb.	181.4 (200) Total	64 (0.028)

[a]EPA, 1973
[b]EPA, 1973a
[c]Hardison and Herington, 1970

- No new high temperature fabrics have become available.
- Insufficient test data exist for making any new definitive judgements about the ability to control particulates during actual furnace operations. These technological factors, combined with the unfavorable economic trends in the industry which were discussed in Section 4.0, strongly indicate that no change is justified.

5.2.2 Extension to Other Emissions

The only logical possible extensions of the standards to other emissions would be for control of fugitive emissions and/or control of specific particulates such as zinc oxide. No other emissions either solid or gaseous appear to warrant specific regulations in light of the declining production in this industry.

There are no demonstrated control methods either physical or chemical for specific control of either metallic fume or zinc oxide in particular. In fact fabric filters are used extensively in the primary zinc industry to collect and recycle zinc oxide dust (Duncan et al., 1973). Although lowering exhaust stream temperature may increase fume control and there are variables in fabric filter control technology which result in slightly different collection efficiencies for various specific particles (Iinoya et al., 1977), the overall efficiency of fabric filters appears to result in control of zinc oxide fume to levels which do not warrant consideration of specific controls.

Fugitive emissions continue to be a problem in many industries including brass and bronze. As indicated earlier the potential for

fugitive emissions from brass and bronze furnaces is quite high during charging and pouring of ingots. In most cases these emissions are very difficult to capture and equally difficult to measure during compliance tests. It was primarily for the former reason that the current particulate standard does not apply during pouring of the ingots (EPA 1973).

The control of fugitive emissions almost always becomes a problem of capturing the polluted air and passing it through an appropriate control device. Control is usually relatively easy once capture of the airstream is made. Effective hooding can improve capture. However, hoods are invariably of custom design, and other operational considerations may necessitate less than optimal hood installations. Such considerations include access to the furnace by heavy equipment for charging and ingot pouring. Only complete enclosure of the furnace can result in full control of fugitive emissions, and such extensive control does not appear economically reasonable in the brass and bronze industry.

5.2.3 Extension to Other Process Steps

The only process step during reverberatory furnace operation that is not currently controlled is the pouring of ingots. As stated above, this step appears at present too difficult to control by any demonstrated economic means. This difficulty has not changed in recent years; therefore, extension of the standard to this process step is not justified.

Several process steps during scrap preparation emit appreciable amounts of particulates (see Table 4-6). These steps include wire burning and sweating furnace operations. From a strictly technological point of view, control of such emissions is both possible and justifiable. However, two practical considerations override the technical capability:

- The unfavorable economic outlook for the industry indicates that most likely no new facilities will be constructed before the next required review of the NSPS.
- Almost all states have general process regulations which should adequately control particulates and opacity from any new or modified facilities.

From an overall viewpoint, extension of the standard to any of these process steps is unjustified at present.

6.0 FINDINGS AND RECOMMENDATIONS

This report assesses the possible need for revision of the existing NSPS for secondary brass and bronze ingot production plants. Since the control of opacity is generally directly related to the control of particulates, all conclusions are based on consideration of the latter.

6.1 Revision of the Current Standard

6.1.1 Findings Based on Control Technology

- Since the standards were originally promulgated, the fabric filter has remained the best demonstrated control technology. No major improvements in this technology have occurred during the intervening period.

- Only one compliance test result is available to assess changes in control capability. Although results of this test were excellent, a far greater amount of new data would be required to justify any change in the standard.

6.1.2 Findings Based on Economic Considerations

- The number of secondary brass and bronze smelters has decreased from 60 in 1969 to 37 in 1976. Currently only 35 smelters are operational.

- Only one smelter has become operational since promulgation of the NSPS. In addition, unfavorable economics required sale of this smelter to a new owner. The smelter is currently operating at 30 percent of installed capacity for only 2 to 3 days per week. There is considerable doubt whether the new owner can achieve a profitable operation.

- Production of brass and bronze ingots in the U.S. has shown a sharp decline over the last twelve years. Only occasional moderate increases were evident during the peak years of the Vietnam War when military demand was at a high level. Production in 1975 was only 54 percent of the peak 1966 level. All available evidence indicates this decline will continue.

6.1.3 Recommendations on Revision of Current Standard

Based upon the technological and economic conclusions, the following recommendations are made:

- No revision of either the particulate or opacity standards should be considered at the present time.
- Periodic studies should be made to monitor both metallic fume control technology and the economics of the brass and bronze industry.

6.2 Extension of Standards

6.2.1 Conclusions Based on Control Technology

- Specific controls for metallic fume or zinc oxide in particular have not been reported in this industry. The best current control technology is the same as for particulates in general.
- Fugitive emissions continue to be difficult to capture and control. Total enclosure is the only completely workable method, although improved hooding or use of additives appear to offer the potential for improved control.
- Control of particulates from other process steps such as wire burning and sweating is technically feasible with standard devices.

6.2.2 Conclusions Based on Economic and Other Considerations

- Standards for control of fugitive emissions or control of particulates from other process steps would impose a heavy economic burden on an industry already in a steep decline.

6.2.3 Recommendations on Extension of Standards

Based upon the technological and economic conclusions stated above, the following recommendations are made:

- Standards for other processes and pollutants are not required at the present time.
- Review of advances in control of fugitive emissions, particularly from other metal industries, should be made periodically to determine if any workable economic techniques have been developed.

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16. ABSTRACT

This report reviews the current Standards of Performance for New Stationary Sources: Subpart M - Secondary Brass and Bronze Ingot Production Plants. Emphasis is given to the state of control technology, extent to which plants would be able to meet current standards, and future trends in the brass and bronze industry. Information used in this report is based upon data available as of October 1978. A general recommendation is made to retain the current standard. Other recommendations include periodic studies of control technology for both metallic fume and fugitive emissions.

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